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1 SYSTEM AND METHOD FOR CARDLESS SECURE CREDIT TRANSACTION
PROCESSING

CROSS-REFERENCE TO RELATED APPLICATION(S)

5 This patent application claims the benefit of the filing date of United States Provisional Patent Applications Serial Nos. 60/219,209, filed July 19, 2000 and entitled "SYSTEM AND METHOD FOR CARDLESS SECURE CREDIT TRANSACTION PROCESSING"; the entire contents of which are hereby expressly incorporated by reference.

10 FIELD OF THE INVENTION

15 The present invention relates to data security and data authentication. Specifically, the present invention is directed to a system and method for extracting unique numerical information from a fingerprint.

BACKGROUND OF THE INVENTION

20 In the last few years, there has been an exponential interest and growth in business transactions over the Internet. The Internet has recently been popularized by the rapid success of the Web. The Web links together a variety of computers from around the world and various topics in a non-sequential network of associations which permit a user to browse from one topic to another, regardless of the format and order of topics. Users 25 access and browse the Web using a web browser that generally resides and is executed on the user's computer.

Billions of dollars are spent every year shopping on the Internet. One can already buy almost anything on the Internet--whether it be a book or a new car. However, there is a major 30 problem with online shopping due to the fact that the Internet is inherently an insecure network. As data packets travel across the Internet, anyone along the way could conceivably intercept and examine those packets. Because of that, there are potential risks to doing business online. Specially if a buyer makes a 35 payment over the Internet with a credit card.

1 A number of ways to make payments across the Internet have
recently sprung up to solve this problem. Most of these methods
use procedures and protocols designed to make financial
transactions on the Internet as confidential as possible, using
5 encryption technology to make sure that no one can steal a credit
card number. Typically, schemes for secure transactions take two
approaches. One approach encrypts personal financial
information, such as a credit card number, so that it can be
transferred across the Internet in a manner that would not let
10 unauthorized people read the data. The second method creates a
system of cyber-dollars, electronic credits that only authorized
merchants can redeem for real money.

15 The Secure Electronic Transaction protocol (SET) has been
endorsed by VISA, MasterCard, American Express, Microsoft, and
Netscape, among other companies. SET describes a way that people
can shop online and have the purchases charged to their credit
cards.

20 In addition to secured credit card transactions, a number
of companies are working on electronic, or "cyber-dollar"
scenarios that will enable consumers to purchase goods and
services anonymously. That is, the consumer uses the digital
equivalent of paper currency to make purchases and need not
provide personal information such as, credit card or bank
information to do so. Using this method of electronic payment,
25 consumers buy electronic "coins" or "tokens" and use these
specially marked and encrypted coins to make purchases.

30 Both credit card systems and electronic cash systems have
their disadvantages. For example, most of the secure e-commerce
web sites provide a secured socket layer (SSL) encryption method
to protect customers' information when transmitted over the
Internet. This method tends to protect the data being
transmitted over the Internet by encrypting the data before it
is transmitted. However, even if it is assumed that a hacker
will not be able to break in this system, a remaining major
35 concern is that merchants have buyers credit card information.

1 Customers use their credit cards to shop online from many online
store. There are many ways these online stores can take
advantage of this information. Furthermore, in case of a credit
card fraud, it would be very difficult to find out who used the
5 credit card without the permission of the card holder. Sometime,
it is the employees or people who have access to the data in any
of the e-commerce companies that a buyer had shopped.

Another concern is having too many credit cards. On
average, a card holder has three credit cards. To solve the
10 problem of having too many cards, many companies are trying to
find the best way to store all of credit card and other
information into a smart card, however, if the smart card is
stolen or lost, then someone may gain access to all the credit
card and personal information. However, smart cards for online
15 shopping transmit credit card information online, even though,
the information is encrypted with a smart card code. Similarly,
merchants can still have access to the credit card information.
Therefore, smart cards like regular credit cards, still provide
the credit card information to merchants and transmit the
20 information over the Internet, which may be intercepted by
unauthorized hackers. Additionally, even with a smart card, the
card holder needs to have the card or memorize the card
information such as, the card number, expiration date, etc.
Additionally, smart cards are prone to being lost.

25

SUMMARY OF THE INVENTION

The system and method of the present invention overcomes the
disadvantages of the existing systems by using fingerprint as a
password or a key to secure data resulting in the following
30 advantages over the existing systems: convenience, flexibility,
portability, different fingerprint sequences can be used for
different purposes, can fit in any crypto algorithm as long as,
the algorithm requires a password, and hardware independent.

In one embodiment, the invention extracts unique numerical
35 information from a fingerprint called Fingerprint To Number (FTN)

1 gateway. A fingerprint is first scanned and the scanned image
is enhanced. The blurred area of the image is restored and the
enhanced image is binarized. The binarized image is then
thinned. A core point in the image is detected and minutiae
5 within a given radius from the core point are detected. A number
is then extracted from the image by computing relation of
minutiae to the core point.

In one embodiment, the present invention provides a computer
data encryption/decryption device and program that uses a
10 fingerprint minutiae generated password to encrypt/decrypt credit
card information before sending the information over a computer
network. The system uses the finger print along with a public
key infrastructure (PKI) and some image processing to ensure the
security of the user's accounts.

15 In one aspect, the invention describes a method for
obtaining a numerical value from a fingerprint comprising the
steps of: enhancing a scanned image of the fingerprint; restoring
the enhanced image; binarizing the restored image; thinning the
binarized image; detecting a core point in the thinned image;
20 detecting minutiae within a predetermined radius from the core
point; and extracting the numerical value by computing relations
of the minutiae to the core point.

In another aspect, the invention discloses a fingerprint
scanning device comprising: means for scanning a fingerprint for
25 obtaining a fingerprint image; means for enhancing the
fingerprint image; means for restoring the fingerprint image;
means for binarizing the fingerprint image; means for thinning
the fingerprint image; means for detecting a core point in the
fingerprint image; means for detecting minutiae within a
30 predetermined radius from the core point; and means for
extracting the numerical value by computing relations of the
minutiae to the core point.

General purpose computers, special purpose computers,
networked computing systems, and/or special hardwares, such as

1 a Digital Signal Processor (DSP) chips are capable of performing
the steps of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

5 The objects, advantages and features of this invention will
become more apparent from a consideration of the following
detailed description and the drawings, in which:

10 FIG. 1 is an exemplary block diagram for the client/server
architecture, according to one embodiment of the present
invention;

15 FIG. 2 is an exemplary process flow diagram showing the use
of a fingerprint to encrypt data, according to one
embodiment of the present invention;

20 FIG. 3 is an exemplary registration process, according to
one embodiment of the present invention;

25 FIG. 4 is an exemplary purchasing process, according to one
embodiment of the present invention;

30 FIG. 5 is an exemplary process flow chart for merchant site
information handling, according to one embodiment of the
present invention;

35 FIG. 6 is a simplified system for a cardless secure
transaction processing, according to one embodiment of the
present invention;

FIG. 7 is an exemplary process flow chart for registration
process, according to one embodiment of the present
invention;

FIG. 8 is an exemplary flow chart for purchasing process,
according to one embodiment of the present invention;

FIG. 9 is an exemplary process flow chart for merchant site
information handling, according to one embodiment of the
present invention;

FIG. 10 is an exemplary diagram depicting examples of how
a numerical value is extracted from a processed image,
according to another embodiment of the present invention;

1 FIG. 11 is an exemplary process flow for extracting a
unique numerical information from a fingerprint, according
to one embodiment of the present invention;
5 FIGs. 12A-B are exemplary diagrams depicting a binarized
imaged obtained from a gray scale image, according to one
embodiment of the present invention;
FIG. 13 is an exemplary diagram depicting a core point,
according to one embodiment of the present invention;
10 FIGs. 14A-B are exemplary diagrams depicting a transformed
image, according to one embodiment of the present
invention;
FIGs. 15A-15D are exemplary diagrams depicting examples of
how a color change is counted, according to one embodiment
of the present invention; and
15 FIGs. 16A-16B are exemplary diagrams depicting examples of
how a numerical value is extracted from a processed image,
according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

20 In one embodiment, the present invention is a system and
method for extracting unique numerical information from a
fingerprint. The system then uses the extracted number as a seed
to generate a variable length of numerical information as a
"password" to use with any encryption formula that requires a key
25 or password to encrypt data. The length of the generated
numerical information "password" depends on the resolution of the
fingerprint scanning unit and the method of numerical information
extraction algorithms. In one embodiment, the numerical
information can be a combination of any number of fingerprints.
30 Furthermore, the information can be more than one persons's
fingerprint combination.

In one embodiment, the present invention uses a fingerprint-
capturing device (scanner) to capture fingerprint image and then
transforms it to a digital image. After image enhancements and
35 pattern recognition processes, digital image is then transformed

1 into numerical information and applied into an encryption formula
5 (algorithms). In another embodiment, the present invention provides fingerprint scanning and transforms the scanned image into a "minutiae" as digital data. This digital data is then used as a "secret key" in a cryptographic formula for data encryption and user authentication. The system creates a binary file based on this minutiae key and securely stores the binary file.

In one embodiment, the invention describes a cardless credit/debit card transaction processing system. The system can store multiple card information in a highly secured manner, thus eliminating any need to carry any credit card or debit card. Biometric methods are utilized to identify and authorized transactions in an encrypted and secure environment. Encryption/decryption methods may be applied using multiple fingerprint sequences rather than only one fingerprint. For example, a login fingerprint can be a left thumb fingerprint while the fingerprint authorization sequence may use the left second finger and the right thumb.

20 In one embodiment, a computer controlled system notifies users about their purchase detail information through a channel of delivery. These channels of delivery include: voice call, pager alert, e-mail, SMS (short messaging system), instant messaging system, facsimile, and the like.

25 In one embodiment, the present invention employs a public kiosk to provide access to Internet through an ISP. FIG. 1 shows a block diagram of a typical Internet client/server environment used by the users in one embodiment of the present invention. PCs (or public kiosks) 220a-220n used by the users are connected 30 to the Internet 221 through the communication links 233a-233n. Optionally, a local network 234 may serve as the connection between some of the PCs 220a-220n, such as the PC 220a and the Internet 221. Servers 222a-222m are also connected to the Internet 221 through respective communication links. Servers 35 222a-222m include information and databases accessible by PCs

1 220a-220n. In one embodiment of the present invention, a
computer program for extracting a unique numerical value from a
fingerprint and providing cardless secure credit transactions
resides on at least one of the servers 222a-222m and is
5 accessible by the potential buyers and credit card holders using
one or more of the PCs 220a-220n.

In one embodiment of the present invention, each of the PCs
(kiosks) 220a-220n typically includes a central processing unit
(CPU) 223 for processing and managing data; and a keyboard 224
10 and a mouse 225 for inputting data. A main memory 227 such as
a Random Access Memory (RAM), a video memory 228 for storing
image data, and a mass storage device 231 such as a hard disk for
storing data and programs are also included in a typical PC.
Video data from the video memory 228 is displayed on the display
15 230 by the video amplifier 229 under the control of the CPU 223.
A communication device 232, such as a modem, provides access to
the Internet 221. Optionally, one or more of PCs 220a-220n may
be connected to a local network 234. An Input/Output (I/O) device
226 reads data from various data sources and outputs data to
20 various data destinations.

Servers (hosts) 222a-222m are also computers and typically
have architecture similar to the architecture of PCs 220a-220n.
Generally, servers differ from the PCs in that servers can handle
multiple telecommunications connections at one time. Usually,
25 servers have more storage and memory capabilities, and higher
speed processors. Some servers (hosts) may actually be several
computers linked together, with each handling incoming web page
requests. In one embodiment, each server 222a-222m has a storage
medium 236a-236m, such as a hard disk, a CD drive, and the like
30 for loading computer software. When a software such as the
software responsible for executing the processes in FIGs. 2-8 is
loaded on the server 222a, an off-the-shelf web management
software or load balancing software may distribute the different
modules of the software to different servers 222a-222m.
35 Therefore, in one embodiment, the computer program responsible

1 for executing the present invention resides on one or more servers.

An exemplary web site location 235 is shown on server 222a in FIG. 1. In one embodiment of the present invention, a secure file including a finger print may be securely stored by a user by accessing web site 235 as described below in more detail. The web site 235 has a unique address that is used by the users to access server 222a (in this example) and the web site location on the server 222a. The computer software for executing the steps of the present invention may also partially reside on the web site 235.

An enormous amount of information is sent and stored over the Internet every day-everything from personal e-mail to corporate data to credit card information and other highly sensitive material. Because the information is sent in packets along public routers, the possibility exists that someone could intercept the information, or retrieve the information from the storage facilities. As a way to ensure that the sensitive material can't be looked at, the present invention uses sophisticated cryptographic system and method so that only the sender can retrieve the data from the remote storage facilities.

The Internet is a notoriously insecure network. Anything that is sent across it or stored in storage connected to it can be tampered with. This is of particular concern when confidential information, such as personal data and credit card numbers, is transmitted and stored across the Internet. Another related concern is that it can be difficult to know that the person sending the information across the Internet, such as credit card information, is really who he says he is. There are ways for people to forge identities and steal credit card numbers, and financial institutions and other businesses require ways to know that the person sending information really is who he says he is.

In one embodiment, the present invention uses finger print based encryption that uses finger prints as encryption keys. The

1 system then uses the encryption key to transmit data over the
Internet. In public key cryptography, two keys are involved: a
public key and a private key. Every person has both a public key
and a private key. The public key is stored in a secure
5 PKIserver and is not publicly available. This embodiment is a
closed system where only the PKIserver can use the public key to
identify the data is coming from the "real" source, not a fake
source. However, the private key is kept secret on the person's
computer. The public key can encrypt messages, but only the
10 private key can decrypt messages that the public key has
encrypted. The invention uses a binary file generated from
scanning the user's finger print as the private key to encrypt
the credit card information and decrypt the data.

15 In one embodiment, the invention uses digital certificates
that use encryption to authenticate the person sending
information, a credit card number, a message, or other data over
the Internet. The system uses human fingerprint to digitally
sign and encrypt the message sent to payment gateway. As a
result, users can shop anywhere in the world, and there is no
20 need to restrict a user to his own computer. When someone with
a digital certificate goes to a site or sends e-mail, that
certificate is presented to the site or attached to the e-mail,
and it verifies that the user is who he claims to be. The
information has been encrypted in a way that makes it unique to
25 the user. In one embodiment, the system of the present invention
utilizes the finger print of the user (explained in more detail
below) to generate a unique digital signature to be used by that
user to verify the authenticity of the user.

30 A typical financial transaction on the Internet works as
follow. Suppose a buyer browses through an electronic catalog
on a Web site and he decides to buy a book. To use the Secure
Electronic Transaction protocol (SET) to pay for the book, the
buyer needs a credit card from a participating bank and a unique
"electronic signature" for his computer. This information will
35 verify who the user is, i.e., what computer the signature is

1 coming from. However, because the certificate is installed on
a user computer ,any person who has access to the user computer
can use the user's account to purchase goods without user's
authorization.

5 The system of the present invention alleviates this problem
by utilizing the account owner's fingerprint for authenticating
and authorizing the account owner. Furthermore the present
invention eliminates fix location problem of today's verification
systems, by no longer requiring installation of certificates on
10 any machine identification purposes. A potential consumer can
freely shop anywhere around the world using any computer or POS
system. Moreover, unlike SET, that can only be used on a card
issuing bank that is a SET member, the system of the present
invention is bank independent, meaning that any bank's credit
card can use the system. This system does not need any bank to
15 join or accept any specific rules or application.

For the system of the present invention, the merchant does
not need to know where the order comes from nor the identity of
the buyer is needed. Since the user uses fingerprint to verify
20 and encrypt information, the system can easily authenticate the
buyer. This design also protects unnecessary personal data
leaks, specially when stored in a third party system, for
example, the merchant's system.

The present invention uses "closed" PKI system for merchant
25 identification purpose. The merchant sends verification to the
buyer that the order has been made. The merchant's software
creates an authorization request for payment and includes with
the merchant's digital signature the transaction identifier and
the PI received from the buyer. The software encrypts all of it
30 and sends the encrypted request to the payment gateway. The
payment gateway decrypts the messages and uses the merchant's
digital signature to verify that the message is from the
merchant. By examining the PI, it verifies that they have come
from the buyer. The payment gateway then uses a bank card
35 payment system to send an authorization request to the bank that

1 issued the buyer his bank card, asking if the purchase can be
made.

When the bank responds that the payment can be made, the
payment gateway creates, digitally signs, and encrypts an
5 authorization (approval) message. This message is then sent to
the merchant. The merchant's software decrypts the message and
uses the digital signature to verify that it came from the
payment gateway. Assured of payment, the merchant now ships the
book to the buyer. Some time after the transaction has been
10 completed, the merchant requests payment from the bank. The
merchant's software creates a capture request, which includes the
amount of the transaction, the transaction identifier, a digital
signature, and other information about the transaction. The
information is encrypted and sent to the payment gateway.

15 The payment gateway decrypts the capture request and uses
the digital signature to verify it is from the merchant. It
sends a request for payment to the bank, using the bank card
payment system. It receives a message authorizing payment,
encrypts the message, and then sends the authorization to the
20 merchant. The merchant software decrypts the authorization and
verifies that it is from the payment gateway. The software then
stores the authorization that will be used to reconcile the
credit card payment routinely when it is received from the bank.

There are many existing encryption algorithms such as, RSA,
25 DSA, etc. All of these encryption algorithms involve altering
the original data into different one by means of performing
certain calculation on the original data. Some systems use
hardware address or ID as a key, however, it requires the user
to perform the encryption/decryption on the same machine.

30 A Public Key Infrastructure (PKI) algorithm uses a
certification authority (CA) and issues a private key that
resides in the user's computer and a public key that is
obtainable by the receiver of the message. If the user wants to
encrypt a message and send it to others, the user has to perform
35 the encryption in his own computer. While the receiver of the

1 message can get the public key to decrypt the message anywhere
around the world.

5 FIG. 2 is an exemplary process flow diagram showing the use
of a fingerprint to encrypt data according to one embodiment of
the present invention. In block 201, a fingerprint scanner scans
10 human fingerprint "live scan" into an image format. Live scan
is a fingerprint scanning process that detects human fingerprints
by temperature, contact pressure, etc. Then, some image
processing is performed to enhance the finger print image in
block 202. Image processing includes noise reduction, image
enhancement, thinning, minutia detection, etc. The digital image
15 of the fingerprint is then converted into a binary number, as
shown in block 203. The system then uses this number as
"password" for an encryption algorithm to encrypt the target
data, as shown in block 204. In block 205, data such as credit
card information is encrypted using the fingerprint-based
password.

20 In one embodiment, password length can be increased to
improve security by using multiple fingerprints and with
different sequence. For example, numbering fingers in 0-9,
starting from left to right. Then, using the two thumbs will be
25 "56" and using both small fingers will be "09". Furthermore, a
larger number of fingers can be used in different sequence and
frequency to obtain an even more secure system.

30 In one embodiment, the credit card information is stored in
a data center, so that the user can access this data at anytime
anywhere using Internet. The data is stored in an encrypted form
which means user has complete privacy for her data. A compatible
fingerprint and a computer program record new member's
35 fingerprint minutiae for system login and identification
purposes. A software program including a specific private key
is used to obtain the member's fingerprint minutiae key, encrypt
it with the private key and send it to the data center to
complete the registration process. The private key is preferably
hard-coded in the program. In one embodiment, an all-in-one

1 device, combines scanner and encryption module in a fingerprint
2 reader unit, with hardware encoded key for encrypted
3 transmission.

4 New member's fingerprint minutiae is sent to the data center
5 in encrypted form with the private key that is sent with the
6 membership package. In the data center, a public key that is
7 stored with user ID in a secured database is used to decrypt the
8 encrypted message. This message is a payload data including the
9 encrypted fingerprint minutiae key from the user. The decrypted
10 message (result) is the original minutiae from the user. This
11 fingerprint is for future login verification purpose. This
12 encrypted message is encrypted with specific private key (the one
13 that was sent to the new member). If member's encrypted
14 fingerprint minutiae key cannot be decrypted in the data center,
15 new member needs to retry the process in order to complete the
16 registration process.

17 Once registration is completed, the member only needs to
18 type in a user ID and position his/her finger in the fingerprint
19 reader. User ID is encrypted with member fingerprint minutiae
20 and is sent to data center for login request. Then, the data
21 center decrypts the user ID with the presorted fingerprint
22 minutiae key. A portable fingerprint reader unit with Internet
23 connection capability may be provided in the post offices (or any
24 other convenience place) for the new member to complete the
25 registration process.

26 In one embodiment, the system of the present invention (M1
27 system) provides services to both existing and new credit/debit
28 card members. Customers register their banking information (like
29 credit card information, debit card information, etc.) with
30 system's Secured Relay Data Center. All customer information are
31 stored in an encrypted form by means of their own fingerprints
32 as a "key". When using this embodiment to purchase goods online,
33 customers simply input their userID and their Login fingerprint
34 scan. The Secured Relay Data Center then displays to the
35 customer a pop up screen that includes data such as, "name of

1 card issuing bank" for the customer to choose from. After
deciding which card to charged to, the customer then use the
system to scan the fingerprint authorization sequence (may have
more than one fingerprints). Banking information is then
5 decrypted from the Secured Relay Data Center and is sent to the
Merchant Bank for credit processing via line with security
capabilities, such as ISO8583.

FIG. 3 illustrates an exemplary registration process
according to one embodiment of the present invention. As shown
10 in block 302, a customer may apply for a system account through
mail, online registration, FAX, etc. Once an account is
established, in block 304, the system checks to see whether the
customer is the owner of the applied banking information, i.e.
credit card, debit card owner etc. If the customer chooses to
15 purchase a fingerprint scanning device, a fingerprint scanning
unit along with the proper software is shipped to customer, as
illustrated in block 306. In block 308, using the installed
fingerprint scanning unit, the system sends the customer login
fingerprint scan to the secured data center 312. If a
20 fingerprint scanning device is not available to the customer, the
customer may visit a service station (e.g., a post office, bank,
etc.) to scan his finger print.

The first time fingerprint registration is encrypted by a
"hard coded" private key in the fingerprint scanner (block 310),
25 then decrypted later with the public key in the data center 312.
In block 318, after successful login to the system, the customer
is required to send in banking information and the fingerprint
authorization sequence scan to a secured database. The
fingerprint authorization may include more then one fingerprint
30 with different sequences. Banking information is then encrypted
using customer's fingerprint authorization as a "Key" and stored
in the secured relay data center 316. As a result, only the
customer can decrypt the banking information using his/her
fingerprint.

1 FIG. 4 shows an exemplary purchasing process according to
one embodiment of the present invention. The customer may
purchase goods and services on any online store. Such store
should have M1 Payment method (the above described embodiment)
5 enabled. The customer can access M1 payment method from any
computing device that has Internet access and has a compatible
fingerprint-scanning device 426. (e.g., mobile device 420, PC
at home 422, public kiosk 424, etc.). In block 402, the customer
enters his userID and the login fingerprint scan. The userID is
10 encrypted with the login fingerprint and sent to the secured
relay data center 416 for login purpose. The system then queries
the database 418 for a list of all registered banking information
by the customer. In block 404, a pop-up screen displays to the
customer information including registered credit/debit card (bank
name only, no number) information on file.

15 The customer can choose which card to use and then submits
fingerprint authorization sequence scan, as shown in block 406.
The encrypted card information is then retrieved from the secured
relay data center database and is decrypted with customer's
20 fingerprint authorization. Card information and purchase details
are then encrypted and sent to merchant bank for credit
processing, as shown in block 408. The credit information is
processed and approval information is returned to the merchant
(the online shop in this case), as shown in block 410. The
25 system then passes the approval information to the Notification
server and sends a purchase notification to the customer
according to his/her preferences in block 412. The notification
can be a voice call, pager alert, Fax etc. The matching server
stores the login fingerprint and the customer registered banking
30 information.

35 FIG. 5 depicts an exemplary process flow chart for merchant
site information handling according to one embodiment of the
present invention. Once in the merchant web site, the customer
proceeds to check out the site and chooses an M1 payment method
in block 502. The customer then enters userID and logs in the

1 fingerprint scan that is sent to the data center in encrypted
form in block 504. In block 505, the userID is encrypted with
login fingerprint and is transmitted to the data center via
Internet with SSL. The server in the data center returns
5 possible choices of credit/debit card issuing bank name in a pop-
up screen, as depicted in block 506. The customer then chooses
credit/debit card name and enters fingerprint authorization
sequence in block 508. In block 509, the payload is encrypted
with merchant side private key and is delivered to the data
10 center.

The server in the data center then looks up credit card information and decrypts the information with customer's fingerprint authorization. The system then encrypts card information and payment details and send them to merchant bank, as shown in block 510. Merchant bank sends the credit process information to data center in block 512. The system then forwards approval information to merchant site via Internet with SSL. A notification with purchase details is then sent to the customer via customer pre-selected channel in block 514. The purchase detail is then returned to the merchant site, as shown in block 516.

FIG. 6 shows a simplified system according to one embodiment of the present invention. A customer visits an online shopping site 608 with M1 payment system enabled using a PC 602 or a mobile device 604 and an ISP 606. The customer can access an online shopping site via any computer device that includes a fingerprint reader. A double firewall infrastructure includes two firewalls 610a and 610b, preferably from two different firewall vendors. This is mainly to prevent hacker attacks on brand name firewall. Login fingerprint information is stored in a database 610a in a matching server 610. The matching server 610 matches a user to a respective financial institution. A pop-up screen displays all registered credit/debit card names. Encrypted banking information storage 620 stores encrypted card information. Only the customer's own fingerprint (fingerprint

1 authorization) can decrypt this information. This action only
occurs when a purchase action is initiated by the customer. A
notification of purchase detail is then sent out to the customer
via a notification server 612 and a notification communication
5 center 614.

In one embodiment, the present invention provides service
to both new and existing credit/debit card customers (M2 system).
With this system, purchasing good and services at any point of
sale (POS), including online shopping no longer require a
10 physical card and pin. In this embodiment, the M2 system uses
a fingerprint reader to collect customer's login fingerprint
(similar to M1 system) and the card number is stored in a
matching server located within individual's card issuing bank's
site. This embodiment allows existing banking systems to remain
15 intact, while incorporating the new biometric identification and
encryption method to provide highly secured electronic
transaction environment.

FIG. 7 depicts an exemplary flow chart for registration
process, according to the above embodiment of the present
20 invention. A customer submits credit/debit card in block 702.
Existing cardholders may also use this service at their card
issuing bank. This is due to credit card information being
stored in a card issuing bank for the above embodiment. The
application goes through normal credit card approval procedures
25 according to individual bank, as shown in block 704. When
application is approved, the customer uses a fingerprint reader
to record login fingerprint scan and obtains a userID, as shown
in block 708. In block 710, the login fingerprint is encrypted
with the service center's private key and is sent to the data
30 center for login and multi-card lookup purposes. The data center
stores the userID and login fingerprint minutiae for multi-card
lookup service in block 712. In block 714, the customer then
enters fingerprint authorization sequence (may be multiple
35 fingers) into the Matching Server located within the card issuing
bank's data center. The Matching Server looks up credit card

1 information when a purchasing action is initiated by the customer. In this embodiment, customer's credit card information is stored in their card issuing bank and the M2 system does not know the customer's card information.

5 The Matching Server located at the card issuing bank's data center stores the userlD and card information, as shown in block 716. This information may include card holder name, card number, expiration date, billing address, etc. When a purchase action occurs, the Matching Server uses fingerprint authorization
10 sequence to decrypt the card information stored in the Matching Server. The system then sends that credit card information and purchase detail to the card issuing bank for credit processing. An optional transaction security check feature is provided to the customer. This feature requires the customer to record one more
15 fingerprint scan (block 718) and stores it in a data Center, as shown in block 720. When the system detects an extensive usage of an account, the customer (Account holder) may be required to present the extra fingerprint scan as an extra security feature.

FIG. 8 depicts an exemplary flow chart for purchasing process according to the above described embodiment of the present invention. In block 802, the customer performs a purchasing action (POS or online store) with M2 Payment method selected. The customer then enters his userlD and the login fingerprint scan in block 802. The data center looks for userlD
25 and the POS system displays to the customer a list of customer registered credit/debit card issuing bank name only, as shown in block 806. In block 810, the customer chooses which credit/debit card to use and submits fingerprint authorization sequence (i.e., one or more fingerprint). Purchase details and fingerprint
30 authorization are encrypted with the data center's private key and then sent to customer's card issuing bank, as illustrated in block 812. The Matching Server decrypts the encrypted information with a public key obtained from the data center and looks up encrypted credit card information from the matching
35 database according to the userlD. The matching server then

1 decrypts the credit card information and sends it to the card
issuing bank with purchase details for credit processing.
Approval information is then returned to the merchant and the
customer via the data center, as shown in block 814.
5 Notification server then sends purchase notification to customer
via a pre-selected communication channel similar to M1 system,
as depicted in block 816.

FIG. 9 illustrates an exemplary process flow chart for
merchant site information handling according to the above
10 described embodiment of the present invention. After the
customer enters in a userID and login fingerprint scan (block
904), the merchant system redirects purchase detail, userID and
login fingerprint encrypted with merchant's private key to the
data center via an Internet connection, as shown in block 906.
15 This merchant system and the POS device are depicted in FIG. 6
as Merchant 630 and POS device 632. Also the merchant Bank site
620 of FIG. 6 is replaced with the Card Issuing bank site in this
embodiment. In block 908, the payload is encrypted in the data
center with merchant's public key. The system then looks up
20 credit/debit card listing (financial institute name only) from
Matching Storage within the data center. The data center then
returns card listing to the merchant's terminal, as shown in
block 912.

The customer chooses a financial institute to be used from
25 the card listing and then inputs fingerprint authorization
sequence in block 914. The data center then encrypts the
purchase detail with the private key. This information is then
redirected to customer's choice of card issuing bank's Matching
Server. The fingerprint authorization sequence for credit card
30 information resides inside card issuing banks' Matching Server.
This means the data center does not store fingerprint
authorization sequence, that sequence only resides in the
Matching server location typically, within the card issuing
banks' site.

1 The Matching Server typically located within the card-
issuing bank then decrypts the payload with the data center's
public key, as shown in block 918. The system then matches the
5 userID and fingerprint sequence to the received purchase detail
and card information and sends it to card issuing bank for credit
processing in block 922. In block 924, an approval code is then
sent to the data center to notify the customer via pre-selected
notification methods. The approval information is then sent to
the merchant. In this embodiment (M2 system), all credit/debit
10 card information retrieval and decryption are performed within
the card issuing bank's data center and there is no need to
modify the existing financial systems.

A fingerprint is typically formed from composite curve
segments. The top part is called "ridges" and the lower portion
is called "valleys." The ridges and valleys alternate, flowing
in a local constant direction. The "minutiae" are the small
features formed by crossing and ending of ridges in the
fingerprint ridges flow pattern. In other words, minutia refers
to the ridge ending and bifurcation of a fingerprint pattern.
20 Other important fingerprint features include: core and delta,
which can be served as a "landmark" for orientation and act as
a "singularity Point".

FIG. 11 is an exemplary process flow for extracting a unique
numerical information from a fingerprint, according to one
25 embodiment of the present invention. In block 1102, gray scale
fingerprint image are scanned from a fingerprint scanner.
Typically a 500dpi (dot per inch) resolution is currently used,
i.e., every inch of scanned image contains 500 pixels of
information. After a gray scale image is acquired from the
30 fingerprint scanner, the system performs an image enhancement
step, as shown in block 1104. This process overcomes some
undesired image degradation effects like wrinkles, scars, dirt,
finger dryness, etc. In one embodiment, this step includes
enhancing contrast and edge of each ridge. Then, an enhanced
35 image is acquired using histogram equalization process. The

1 histogram equalization process is well known to people skilled in
the art of image processing. The noise in the image is then
filtered out. The ridge is then distinguished from the blank
area (valley) by sharpening the edges of the ridge. Finally, the
5 rough edges of each ridge are smoothened out.

In block 1106, the blurred image acquired during scanning
is restored and the noise is filtered out again. The geometric
distortion is corrected and, inverse filtering and least means
square filtering, such as the well-known Wiener filtering are
10 then applied.

Before thinning the image lines, gray-scale image should be
transformed into binary (black and white) image. As shown in
block 1108, the gray scale image is converted to a black-and-
white image through a binarization process. Gray-scale image
15 typically has an intensity level between 0 to 255. Intensity
level 0 means black and intensity level 255 means white. (for
gray-scale, intensity level can be regarded as a degree of
brightness) As a result of converting gray scale image into
binary image, the image lines are changed to black and between
20 the lines are filled with white. If scanned image has lines with
similar intensity level, the image can be easily transformed by
setting a threshold of a certain intensity level. In this case
if the line's intensity level is lower than that of threshold,
it is changed into black and the blank area are filled with
25 white.

In most cases, however, it is very difficult to obtain a
clear image that includes lines with similar intensity levels.
To overcome this problem, the method and system of the present
invention performs the following steps. The image is partitioned
30 and divided into several small areas. Then, an average intensity
level of lines within an area is calculated. This average
intensity is set as a threshold and the gray-scale image of the
area is transformed to binary image. This process is then
repeated for each partitioned area until binarization is

1 completed. FIG. 12B depicts an exemplary binarized imaged
obtained from a gray scale image of FIG. 12A.

5 A binary to skeleton processing, called "thinning" may also
be performed on the image, as illustrated in block 1110. A
skeleton image is produced by eroding the objects within a binary
image until they are one pixel wide. In other words, the width
of the black lines are thinned to 1 pixel. The advantage derived
from using a skeleton image is that extraction of ridge features
becomes a relatively straightforward procedure based on tracing
10 line segments. In one embodiment, the well known method
described in T. Y. Zhang and C. Y. Seun, A Fast Parallel
Algorithm for Thinning Digital Patterns, journal of
Communications of ACM, 1984, 9, 236-239, the entire contents of
15 which are hereby incorporated by reference; is used to perform
the thinning.

20 After a skeleton image is generated from the gray scale
fingerprint image, the core point of the fingerprint is
determined in block 1112. A core point is defined as center of
a fingerprint, where the direction lines meet each other, or on
ridge line, as shown in FIG. 13. To detect the core point of an
image, a core area needs to be detected first. To detect a core
area, the image is first segmented, i.e., the thinned image is
divided into square areas, for example areas of 8x8 pixels with
only one or two black lines.

25 This process shortens the time required for processing an
image. For example, using the above segmentation, it takes 1/64
of the time required for processing a 256x256 pixel image without
segmentation to search the same image. After segmenting the
30 image, a Fast Fourier Transform (FFT) process is applied to each
square area. The FFT process enables a computer program to
recognize a line in a given area as a combination of dots, and
also recognize the density of dots along a line. For example,
even on the same line, the density of dots may be high on some
area and low on other areas. A direction line vertical to the
35 tangent of a given line in each segment is then extracted. This

1 line represents the direction of a line that can be obtained by
slicing the line at a given point. That is why FFT process is
applied to fingerprint image.

5 As a result of the above process, the image of the
fingerprint is replaced with the combination of straight lines
crossing from one side to the opposite side of the square area,
as shown in FIGs. 14A-14B. The straight lines are then
classified into 4 types; vertical, horizontal, a slope with left
end high, and a slope with right end high. Each type of line is
10 numbered from 0 to 3 in order. As a result, the fingerprint
image is transformed into a matrix of 32x32(squares). The matrix
is then processed by the column using the following two methods.
Note that, a column which includes core area has the largest
number of squares which are filled with vertical direction lines.

15 A. Core area exists on a column which has the most squares
with number zero (vertical direction lines), or

B. Core area exists on a square whose upper squares in the
same column all have number zero.

20 As a result of the above methods, several squares may be
obtained. Core point exists on the square that meets the
condition of definition B.

25 To detect the core point (pixel) within the detected core
square, the detected core square obtained above, together with
its neighboring squares are further segmented to smaller squares
of 4x4 pixels. The above process for detecting core square is
applied to the smaller square(s) to detect a smaller core square.
The highest pixel on a smaller core square that is on the ridge
line is the core point (pixel).

30 After the core point is detected, the minutiae have to be
detected. Although, every fingerprint image has several
minutiae, in one embodiment, only the bifurcation minutiae are
detected. First, every 3x3 pixel window is processed to detect
connectivity of the pixels within each window. The number of
times that color changes from black to white is then counted.
35 FIGs. 15A-15D depict examples of how the color change is counted.

1 In FIG. 15A, the color changes from black to white twice, i.e.,
B to C, and F to G for a line. Thus, the central pixel (A) is
tagged with a number 2. In FIG. 15B, the color changes from
black to white only once, i.e., B to C, for a termination. Thus,
5 the central pixel is tagged with a number 1. In FIG. 15c, the
color changes from black to white three time, i.e., B to c, D to
E, and F to G for a bifurcation. Therefore, the central pixel
is tagged with a number 3. Finally, in FIG. 15D, the color
changes from black to white three times, i.e., B to C, D to E,
10 and G to H for a bifurcation. As a result, the central pixel (A)
is tagged with a number 3. Thus, the pixels flagged with a
number 3, are bifurcation minutiae where a ridge splits. Next,
pixels with bifurcation'are sorted by the order of their distance
from the core point.

15 The final process is extracting a unique number from the
image, as shown in block 1116 of FIG. 11. Some exemplary methods
to accomplish this task are described below. The first method,
numbers the pixels with bifurcation by the order of their
distance from the core point, b1, b2, b3, b4, b5, b6, . . . , etc.
20 The distance between the core point and b1 = d1, and distance
between b1 and b2 = d2 are calculated. Next, a circle with core,
b1 and b2 on its circumference is drawn, and its radius r1 is
calculated, as shown in FIGs. 16A and 16B. The first part of the
numerical information, d1, d2, r1 is acquired in order. Then,
25 the distance between b2 and b3 = d3 is calculated, a circle with
b1, b2 and b3 on its circumference is drawn, and the radius r2 is
calculated. The second part of the numerical information, d3,
r2 is then obtained in order. Then, the distance between b3 and
b4 = d4 is calculated, a circle with b2, b3, and b4 on its
30 circumference is drawn, and the radius r3 is calculated. The
third part of the numerical information, d4, r3 is then obtained
in order. The above procedure is repeated with all bifurcation
pixels within a certain distance from the core point. As a
result, the number obtained from the fingerprint is in the form
35 of d1d2r1d3r2d4r3d5r4

1 A second exemplary method for extracting a unique number
from the image is shown in FIG. 10. This method re-orients the
image to a direction, for example, parallel to y-axis. Then,
5 from the detected core point, on a circle with a radius r,
sampling points are obtained. A sampling point refers to a
vector of ridge flow pattern (flow direction), as shown in FIG.
10. Eight sampling points information are then combined into a
numerical value, as shown in FIG. 10.

10 According to a third exemplary method, from the detected
core point, a circle with a radius r is reached and minutiae in
different segments within that radius are detected. Then, the
numbers of ridges between the core point and the reference
minutiae are counted, and added up to obtain the numerical
value.

15 The above method may be carried out using a general purpose
computer, a special purpose computer, a networked computing
system, or a special hardware, such as a Digital Signal Processor
(DSP) chip. As described above, any or all of the hardware for
performing the above steps may be embodied in a single
20 fingerprint scanner device. After a unique numerical value is
determined from the fingerprint, the numerical value may be used as
a password, or a key that is used by an encryption module for
data encryption/decryption, or other data security purposes.

25 It will be recognized by those skilled in the art that
various modifications may be made to the illustrated and other
embodiments of the invention described above, without departing
from the broad inventive scope thereof. It will be understood
therefore that the invention is not limited to the particular
embodiments or arrangements disclosed, but is rather intended to
30 cover any changes, adaptations or modifications which are within
the scope and spirit of the invention, as defined by the appended
claims.